AD-A192 676 ALTERATIONS IN UPPER EXTREMITY MOTOR FUNCTION IN SOLDIERS DURING ACUTE HI..(U) ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE NATICK MA A J HAMILTON ET AL. 1/1

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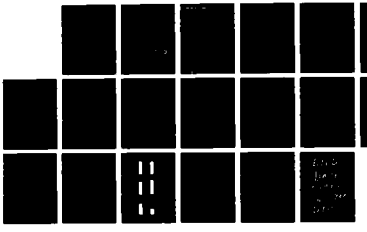

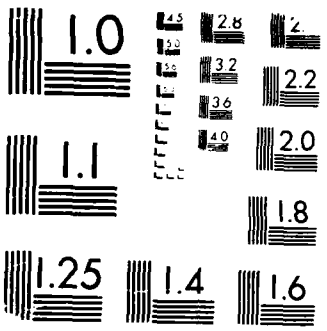

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1988 USU Surgical Associates Day - Jospeh H. Baugh Resident's Award Submission

ALTERATIONS IN UPPER EXTREMITY MOTOR FUNCTION IN SOLDIERS DURING ACUTE HIGH ALTITUDE EXPOSURE

mar 1988

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Running Title: Altitude and Motor Function

Report No.
USARIEM-M-31/88

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Title Alterations in Upper Extremity Motor Function in Soldiers During Acute High Altitude Exposure

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Intended for publication in N/A

Intended for presentation before 1988 Uniformed Services Univ. Surgical Associates Day

Location Bethesda, MD Date 1-2 April 1988

2. Budget Project No. 3M161102BS15 Cost Code 8460082101041

3. Attached contains no classified material. It meets accepted standards for scientific accuracy and propriety. It contains no potentially sensitive or controversial items.

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Abstract:

Acute Mountain Sickness (AMS) is a syndrome of inadequate acclimatization to the diminished concentration of oxygen available at high altitude. In its mild form, it is almost solely a symptomatic illness and physical examination is usually unremarkable. We hypothesized that, while clinical examination might be insensitive for the detection of quantifiable changes, computerized measures of neurological function could be capable of noninvasively measuring and analyzing decrements in neurological function at high altitude. For this reason, a device was designed and tested called an upper extremity movement analyzer (UEMA) which employs magnetic coil search technology to record movements of a subject's upper extremity. Software programs were developed which analyze the recorded movements of a pen stylus between a common start position and a randomly generated series of target positions on the digitizing tablet. The following functions of upper extremity motor function were derived: peak and average velocity (V_p and V_a), maximum acceleration (Acc) and deceleration (Dec), and area and length errors (A_e and L_e). A study was undertaken to examine the effects of simulated high altitude exposure on upper extremity motor function. Eight subjects were exposed to 430 Torr (equivalent to 4,600 m) for 30 hrs. Subjects were first tested at SL and then at 18 hrs and 30 hrs. Clinical assessments, neurological examinations, and environmental symptoms questionnaires (ESQ) were performed serially to compare with UEMA. The subjects were moderately ill with AMS during their hypobaric exposure and UEMA revealed significant ($p<0.01$) mean declines at 30h from 33% to 54% in V_p, V_a, Acc, and Dec but not A_e or L_e in comparison to sea-level (SL) values, suggesting that the CNS maintains accuracy at the expense of speed at altitude. The findings support the hypothesis that computerized devices can noninvasively detect CNS dysfunction during mild hypoxemia at high altitude. Neurological examination proved insensitive in detecting any abnormalities other than a decline in items related to mental status. Declines in UEMA speed-related parameters such as V_p were significantly ($p\leq 0.02$) correlated with the severity of AMS symptoms. UEMA offers the possibility of quantifying the degree of neurologic impairment attendant with AMS as well as detecting subtle alterations in upper extremity motor function. UEMA could be employed in the evaluations of patients with neurological deficits to document progression of disease or reponse to therapy.

KEYWORDS: Acute Mountain Sickness (AMS), Altitude, Arm Movement, Computerized Measures, Digitizer, Hypoxia, Motor Function

High terrestrial elevation imposes a hypoxic burden on the central nervous system (CNS) of the unacclimatized individual. Acute Mountain Sickness (AMS) is a symptomatic syndrome brought on by inadequate acclimatization to hypoxia. Before AMS becomes life-threatening, it is largely a symptomatic illness, characterized by headache, lethargy, malaise, dizziness, irritability, insomnia, nausea and occasional vomiting. Several lines of evidence suggested that cerebral dysfunction as a direct consequence of hypoxia or indirect sequelae of hypoxia-induced swelling played an important role in the pathophysiology of AMS (11).

The symptoms of early AMS closely parallel those early symptoms seen in clinical populations of patients suffering from raised intracranial pressure (ICP) (11). A handful of post-mortem specimens from climbers who had died from high altitude cerebral edema (HACE) had shown neuropathological evidence of diffuse cerebral swelling and many of these climbers had been noted to exhibit neurological deficits during the course of their illness before they died (11). In addition, several studies of participants in mountaineering expeditions have had documented neurological abnormalities (11). Finally, there were compelling theoretical and experimental reasons to believe that neurological function could be quantitatively assessed at altitude. The central nervous system (CNS) is an organ system critically dependent upon adequate oxygen delivery to maintain its function. Earlier psychomotor studies have demonstrated that relatively mild hypoxia can have a significant effect of visual function (13,14) and hand movement (19). Hypoxia, ischemia and raised ICP secondary to cerebral edema or hydrocephalus have been shown to alter electrical impulse propagation along the central motor pathways in animals (3,18) and man (2,7,10). Electroencephalographic recordings from normal subjects at sea level and subsequently at a modest elevation of 3,500 m have also demonstrated increased alpha-wave activity compatible with diffuse cortical depression (17).

These lines of evidence led us to hypothesize that subclinical changes in motor function secondary to either hypoxia or cerebral edema at high altitude might be amenable to detection and analysis by computerized measures. Earlier studies had successfully employed digitizing tablets (21) to demonstrate the effect of visual guidance on trajectory-related properties of arm movement. It was felt that magnetic search coil technology could be employed to demonstrate decrements in motor function at altitude. A study was undertaken to evaluate a prototype device, called an upper extremity movement analyzer (UEMA), and determine changes in upper extremity motor function in man during an acute simulated altitude exposure. Serial assessments were performed with a standardized Environmental Symptoms Questionnaire (ESQ), clinical interviews and neurological examinations to permit a comparison between results obtained with UEMA and the subjects' symptomatic and clinical picture during their altitude exposure.

METHODS AND MATERIALS

A. Subjects

Eight healthy, male soldiers served as test subjects after giving their informed consent. All subjects were life-long residents at low altitude, and none had experienced any exposure to altitudes greater than 2500 meters in the six months immediately preceeding the study. Each subject's medical history was reviewed and a physical examination and laboratory screening performed prior to inclusion in the study. The mean (± S.E.) age, height, weight of the subjects were 24 (± 4) years of age, 176 (± 3) cm in height, and 75.3 (± 3.4) kg, respectively. All subjects were right-hand dominant.

B. Experimental Design

The study employed a repeated measures design to determine changes occuring during hypoxic exposure. Subjects first received a complete

orientation and familiarization with all the tests and procedures. Prior to actual sea-level collections, each subject underwent two UEMA runs to ensure that reliable results were being generated.

After sea-level baseline testing was completed, the subjects underwent rapid decompression (300 m/min) in the hypobaric chamber facility at the Altitude Research Division, U. S. Army Research Institute of Environmental Medicine (USARIEM), Natick MA to a final barometric pressure of 430 Torr (equivalent to 4,600 m). Subjects resided in the altitude chamber at that pressure for 30 hours.

C. UEMA

UEMA is a noninvasive computerized device designed and developed at USARIEM to measure and analyze upper extremity motor performance. The device employs a digitizing tablet (Altek Corp. Model No. R-22; Silver Springs, MD) to record and measure several different aspects of upper extremity movement. The translucent tablet measures 73 x 73cm and is backlit with an array of light-emitting diodes (LEDs). The LEDs are arranged into an origin which is the constant "starting" position for each trial and an array of targets 40 to 60 cm distant from the origin (see Figure 1).

Figure 1 -- about here

A given subgroup of targets can be selected by computer (Hewlett Packard 9836; Lexington, MA) so as to provide an adequate distance between origin and target to ensure that each subject is required to employ movement of his whole upper extremity to carry out the required movement between origin and target. In this fashion, subjects of different sex or body build (and hence different arm lengths) can be accomodated with a single device.

Figure 2 -- about here

The subject holds a pen stylus in his dominant hand and is asked to move the stylus as quickly and accurately from the origin to one of the LEDs in the selected group of targets. Once, a group of targets has been chosen to provide a full uppper extremity movement, the computer (see Figure 2) assigns a random order to the sequence in which targets at the specified distance are presented to the subject. This ensures that there is no anticipatory movement on the part of the subject as to which target will be presented next. Information about the movement and position of the stylus is collected by the digitizing tablet at a rate of 100 times per second and stored in the computer. Software programs were developed to measure the following variables: (1) the peak and average velocities of the arm movement (V_p and V_a, respectively), (2) the maximum acceleration (Acc) and deceleration (Dec), (3) area error (A_e), (4) length error (L_e). A schematic computer print-out of a single trial is depicted for discussion purposes in Figure 3. A_e is the area between a subject's actual tracing and ideal straight line between the origin and target. L_e determines the distance by which a subject overshot or undershot the target (represented as positive or negative numbers, respectively).

Figure 3 -- about here

After familiarization with the device, the subject is asked to perform five separate trials for each of four assigned targets. All five trials for a target are averaged to yield mean V_p, V_a, Acc, Dec, A_e and L_e for a given LED position. An average experimental run for five trials for each of four targets requires fifteen minutes per subject. Subjects were permitted two practice runs to familiarize themselves with the equipment and testing procedures. Subjects were not permitted to see on-going data analysis from their UEMA trials. After sea-level familiarization was completed, subjects were not permitted further practice. A subject's last two sea-level runs were employed to yield his sea-level baseline motor performance and then compared to data later obtained during serial testing at altitude.

D. Arterial Blood Gas (ABG) Determinations

During the SA study, pO_2, pCO_2 and pH determinations were performed on heparinized samples obtained from the radial artery before ascent and then at the end of 30 hrs exposure before descent to sea level.

E. Environmental Symptoms Questionnaire (ESQ)

The ESQ is a 67-question inventory of symptoms which can occur in stressful environments including heat, cold, and high altitude (16). It was administered to subjects individually using an interactive computer software package (6). The program queries each subject about specific symptoms which he then rates based on six phrases ranging from "not at all" to "extreme". The responses were assigned numbers from 0 (not at all) to 5 (extreme), and a weighted average of cerebral symptoms termed "AMS-C" and respiratory symptoms termed "AMS-R" were derived from the scores. These measures have been shown in previous studies to accurately and reliably identify individuals suffering from AMS (16). ESQs were adminstered at SL every 12 h during the 36 hours before ascent. ESQs were then administered at 2, 18, and 30 h of altitude exposure.

F. Clinical Assessment

The clinical assessments were performed by one of two physicians experienced in altitude-induced medical problems. Physicians interviewed each soldier and recorded the presence of specific altitude-related symptoms such as headache, nausea, dyspnea, and sleep disturbances and examined subjects for the presence of rales (indicative of high altitude pulmonary edema) or peripheral swelling. The clinical assessment was scored in the following manner: 0-no symptoms; 1-mild headache or nausea; 2-moderately severe headache and nausea; 3-moderately severe headache, nausea, vomiting or some combination of these; 4-all the findings included in 3 plus rales or peripheral edema. A score of greater than 1 was considered mild AMS; greater than 2 was considered moderate AMS (15). Clinical assessments were performed on the same schedule as ESQs.

G. Neurological Examination

A neurological examination was performed by a physician experienced in both neurology and altitude-related illness. The examiner employed a standardized neurological examination which included a mental status examination testing short term and long term memory, calculation and attention span. In addition the examination included specific testing of all cranial nerves, motor and sensory function in all four extremities, all major spinal reflexes, and both cerebellar and equilibrium testing. It should also be noted that the neurological examination employed was specifically designed to test upper extremity strength and movement so as to provide a detailed clinical evaluation of the same functions that were being tested with UEMA. After each examination, a detailed standardized record of each mental status and neurological test was completed by the physician. Neurological testing was performed at SL, and then at 2 h, 18 h, and 30 h of altitude exposure.

H. Statistical Analyses

Values are represented as a group mean ± S.E. unless otherwise noted. A one-way analysis of variance (ANOVA) for repeated measures was performed separately each of the following variables: UEMA variables, ABG measures, AMS-C scores derived from the ESQ, clinical assessment scores, and each of the six UEMA variables. Time of sampling during each of the studies was employed as the main factor in the ANOVA. For UEMA, an additional analysis was performed with target position as a second fator in a 2-way ANOVA to determine if target location was a significant factor in motor function parameters. Post hoc significant differences were identified using the Tukey's test (1). A p value of ≤ 0.05 was accepted as indicating statistical significance unless otherwise indicated. A multiple linear regression was performed to determine if the severity of AMS symptoms as elicited by ESQ was correlated with alterations in motor function as measured by UEMA.

RESULTS

1. UEMA

All subjects were tested with the stylus in their dominant hand. There was an unexpected but significant increase in speed-related parameters for targets in the right side (mean V_p=239 ±18 cm/s) of the target array as compared to those on the left-side (mean V_p=221±13 cm/s). Also unexpected was the finding that this significant left-to-right shift in V_p was no longer significant once the subjects were exposed to high altitude.

The group exhibited significant mean decrements in upper extremity motor function during the course of their exposure (see Figure 4). There was a 34% decline in mean V_p from 230 (±15) cm/s at SL to 158 (±9) cm/s at 30 h of exposure ($p \leq 0.01$). Similarly, mean V_a declined by 34% from 89 (±7) cm/s at SL to 59 (±5) cm/s at 30 h ($p \leq 0.01$). Mean Acc declined 46% from 1901 (±189) cm/s^2

at SL to 1024 (±141) cm/s^2 at 30 h ($p \leq 0.01$). Mean Dec declined 54% from 2123 (±216) cm/s^2 to 990 (±86) cm/s^2 at 30 h ($p \leq 0.01$). Suprisingly, neither mean A_e or L_e showed any signficant changes during SA exposure. A_e averaged 46.1 (±8.9) cm^2 at SL and 46.1 (±16.0) at 30 h of SA exposure. L_e averaged +1.77 (±0.62) cm at SL and +1.34 (±0.61) cm at 30 h.

Figure 4 -- about here

2. ABG Determinations

Group mean ABG data is summarized in Table I. As expected, there was a significant ($p < 0.0001$) decrease in PaO_2, $PaCO_2$, and rise in pH after 30 hrs of hypoxic exposure.

Table I -- about here

3. ESQ

ESQ scores referring in particular to cerebral symptoms were subtracted from the body of the questions and a separate subscore (AMS-C) was derived by methods previously described (Sampson et al., 1983). Mean (± S.E) AMS-C scores are displayed in Table II.

Table II -- about here

Subjects reported a significant rise in cerebral symptoms as indicated by AMS-C scores within two hours after beginning their exposure to 4,600 m. Although there was a notable decline in the severity of their symptoms during the course of altitude exposure, as a group the subjects remained significantly ill with AMS throughout the duration of their exposure.

4. Clinical Assessment

Clinical assessments scores by accompanying medical officers showed a slightly different trend than was demonstrated with the ESQ surveys. The mean (±S.E.) clincial ssessment scores are displayed in Table II.

The subjects were not judged to be ill at 2 hrs with a mean score of 0.0 (±0) despite the severity of their own subjective assessment of symptoms. By eighteen hours, however, the subjects were judged to be moderately ill with a mean score of 2.375 (±0.42) and remained mildly to moderately ill during the remainder of SA exposure with a mean clinical assessment score of 1.625 (±0.37) at 30 hrs.

5. Neurological Examinations

The results of the serial neurological examinations are displayed in Table III. Any significant neurological finding during the course of the study was noted. Detectable changes from sea-level examinations were confined to

alterations in mental status such as memory deficits or difficulties with serial calculations. It is noteworthy that there were no abnormalities elicited in the areas of motor function in terms of strength, pronation drift, rapid alternating movements of the fingers or hands, sensation, appendicular cerebellar exam, or spinal reflexes.

Table III -- about here

6. Correlation of Symptomatic and Clinical Findings with Neurologic Measures

Figure 5 depicts the temporal profiles in mean AMS-C and clinical assessment scores during the study. Subjects were moderately ill with AMS (between 18 hrs and 30 hrs mean AMS-C scores and clinical assessment scores ranged from 3.03 to 1.74 and from 2.375 to 1.625, respectively). A multiple linear regression between AMS-C scores and percent decline V_p from sea-level baseline (see Figure 6) showed a r coefficient of 0.6667 (df=10) which is significant ($p \leq 0.02$).

DISCUSSION

The results support our initial hypothesis that computerized devices can be successfully employed to detect declines in upper extremity motor function among individuals acutely exposed to high altitude. Furthermore, clinical examination in this particular population of subjects with mild to moderate AMS proved to be insensitive at detecting any abnormalities other than changes in items included in the mental status examination. Specifically, there were no

abnormalities of upper extremity function detected by physical examination. This finding supports the contention that computerized measures such as UEMA can be more sensitive in uncovering subtle neurological dysfunction among individuals mildly to moderately sick with AMS at altitude than a physical examination. These results point out the extent to which soldiers can display neurological impairment at high altitude and still not develop overt clinical manifestations.

The study demonstrates that declines in UEMA speed-related parameters were significantly correlated with symptomatic indices of AMS among this group of test subjects who were moderately ill with AMS. While, at first, it might seem intuitively obvious that subjects who became sick with AMS would be more likely to show declines in motor performance, this is not necessarily a correct assumption. Many neurological functions, such as equilibrium (5), visual or auditory function (13), can show significant decrements either very early during hypoxic exposure before AMS can manifest itself or at altitudes below which subjects do not usually experience symptoms. Evidence of hypoxic dysfunction does not constitute *a priori* evidence of AMS.

Since individual thresholds for symptoms may vary substantially, it is difficult to quantitatively compare the severity of AMS in one subject to another. The ESQ suffers from several other drawbacks as well. It is entirely dependent upon the individual subject's own assessment of his symptoms. The ESQ can only distinguish a significantly symptomatic individual from one who is asymptomatic. Furthermore, it does not permit a quantitative comparison between two different symptomatic subjects since one cannot determine if one person is more stoic about his illness than another. Similarly, intra-subject comparisons can be difficult other than documenting that a subject's development or recovery from AMS since symptoms may have been perceived as more severe at one point in time versus another. Nonetheless, the ESQ has served as an important vehicle for documenting the presence of AMS and for determining the effectiveness of pharmacologic prophylaxis for altitude illness. The finding that UEMA speed-related parameters are significantly correlated with

the severity of AMS offers the capacity to quantify mild to moderate AMS without relying solely on subjective responses to symptomatic questionnaires or clinical interview questions.

Speed-related UEMA parameters were adversely affected by hypoxia while accuracy-related parameters were not significantly different from sea-level control values. The subjects were able to maintain accurate arm movements during altitude exposure but only at the expense of a sizeable fall in the velocity, acceleration and deceleration of these movements. Cerebral hypoxia may partially interfere with motor control at the supraspinal level and accurate arm movements can only be accomplished with a loss of speed. Electroencephalic graphic recording support the contention that there is diffuse slowing during mild hypoxic exposure (3,500 m) (17). It is impossible, however, to rule out end-organ dysfunction due to a direct effect of hypoxia on nerve transmission, the neuromuscular junction, or the effector muscles themslves. A recent study does, however, shed some light on this issue. Willer et al. (20) examined recruitment curves of the monosynaptic Hoffman (H) reflex and of the direct motor (M) excitation of aplha-motor fibers of the posterior popliteal nerve in seven subjects exposed to normobaric hypoxia (end-tidal O_2 concentrations of 6-7%). The subjects exhibited increased peripheral excitability as demonstrated by a 50% increase in the amplitude of the H response after only 12 minutes of hypoxic exposure. However, simultaneously, there was also evidence of decreased excitability of the spinal elements of the monosynaptic reflex during hypoxia as evidenced by a decrease in maximal H to maximal M response. These findings led the authors (20) to hypothesize that while hypoxia appears to produce a peripheral hyperexcitability there is a simultaneous central (supraspinal) inhibitory effect on spinal motor neurons. This would suggest that central processes may be preferentially inhibited rather than peripheral effector organs. At present, there is no data available on the behavior of the muscle-nerve junction as a possible site where hypoxia may exerting its effects.

It is interesting that our right-handed test subjects demonstrated a decidedly higher velocity for targets on the right side of the UEMA tablet. Since this study, we have had an opportunity to test three left-hand dominant subjects with UEMA and they have all demonstrated statistically significant increases in velocities for targets located on the left side of the array (data not shown). One possible explanation is that movement of the hand across the body to targets opposite the dominant side partially blocks the view of the target itself as the hand approaches it. This interference with one's ability to constantly visualize the target may cause one to slightly reduce the speed of his arm movements. Subjects may be able to extract a slight increase in velocity of arm movements to the dominant side under normal conditions but, as hypoxic conditions force subjects to slow down their movements, the left-to-right shift is abolished. Still, it is difficult to explain why this left-to-right shift is abolished during hypoxic exposure if visualization of the target were the only factor influencing V_p. Alternatively, since visual thresholds for acuity and light intensity discrimination have long been known to be significantly raised by hypoxia at altitudes equivalent to those employed in this study (14), the ability to visualize the target under hypoxic conditions may have a less pronounced effect on arm speed than at sea level. Further studies are under way to try to elucidate this unexpected finding.

With respect to comparing computer-derived quantitative measures of neurological function and clinical measures, these results illustrate several important points. First, a detailed neurological examination failed in every instance to reveal abnormalities in function (other than mental status items). Cognitive function as measured by short term memory (4), logical reasoning tasks (8,9), and attention span (12) have been documented to be quite sensitive to the effects of acute mild hypoxia. It is therefore not suprising that there were significant findings in this area of the serial neurological examinations. Nor is it surprising that the remainder of the neurological examination was unremarkable under these conditions of relatively mild hypoxia. It is noteworthy, however, that the decline in motor function as elicited by UEMA measures was seen in subjects who appeared overtly to be functionally intact.

Mild hypoxia offers a novel way to produce a reversible neurological dysfunction in normal test subjects. These results offer insight into the neurological sequelae of acute hypoxia such as can occur with high altitude exposure or with specific pulmonary or cardiac pathologies. The findings also serve to underscore what a fruitful laboratory setting high altitude can offer in the realm of neurological research. Studies are currently planned to perform UEMA testing in a clinical population with known movement disorders to determine how speed- and accuracy-related UEMA parameters may be affected by disease processes. It is hoped that such quantifiable computerized measures will also offer a method whereby progressive neurological diseases can be followed and response to therapy documented.

In summary, several significant findings have emerged from this examination of neurological function during the course of 30 hours of hypobaric exposure equivalent to an altitude of 4,600 m:

(1) High altitude exposure is associated with quantifiable neurological dysfunction in upper extremity motor in neurologically normal subjects.

(2) Computerized devices to detect neurological dysfunction, such as the prototype UEMA, are more sensitive than a clinical examination at detecting changes in motor function at high altitude.

(3) Quantifiable changes in speed-related parameters of arm movement as detected by UEMA are significantly correlated with the severity of AMS.

(4) Data from UEMA supplements other clinical and experimental observations suggesting suprapsinal dysfunction occurs as a result of mild hypoxia.

(5) Computerized measures of neurological function possess great potential as new technologies for the diagnosis of altitude sickness and as measure to

asess the efficacy of pharamacolgic prophylaxis and treatment of AMS. Both technologies also have wide application in the civilian neurologic and neurosurgical populations in quantifying handicaps and documenting the efficacy of rehabilitation and treatment.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the valuable assistance of MAJ Paul Rock, SSG James O'Connell, SP4 William Scott, SP4 David Zahn, SP4 Robert Aguzzi, Mr. James Devine, Mr. Chares Fulco and Mr. Edward Powers. CPT Hamilton (MC, USAR) also gratefully acknowledges the support of COL David Schnakenberg, Commander, USARIEM, Natick, MA; MAJ Malcolm Westcott, Officer-in-Charge, First Army Augmentation Detachment, Ft. Meade MD; and Dr. Nicholas T. Zervas, Chairman, Neurosurgical Service, Massachusetts General Hospital, Boston, MA for their continued encouragement and support in this scientific endeavor.

Human subjects participated in these studies after giving their voluntary informed consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on the use of volunteers in research. The subjects' participation and determination in undergoing the rigors of altitude exposure is gratefully acknowledged.

The views, opinions, and findings contained in this report are those of the authors and should not be construed as an official Department of the Army position, policy, or decision unless so designated buy other official documentation.

TABLE I: MEAN (±S.E.) ARTERIAL BLOOD GAS DATA

	Sea Level	Altitude (15,000 ft) 30 hrs
PaO_2	98.8 (±1.6)	40.9 (±1.3)*
$PaCO_2$	39.9 (±1.9)	29.9 (±0.6)*
pH	7.38 (±0.06)	7.45 (±0.005)*

* denotes a value significantly ($p<0.0001$) different from sea level values

TABLE II: MEAN (±S.E) SYMPTOMATIC & CLINICAL ASSESSMENT SCORES

A. AMS-C SCORES FROM ENVIRONMENTAL SYMPTOMS QUESTIONNAIRES

Sea Level	Altitude		
0 hrs	2hrs	18hrs	30hrs
0.09 (±0.04)	2.59 * (±0.55)	3.03 * (±0.43)	1.74 * (0.48)

B. CLINICAL ASSESSMENT SCORES

Sea Level	Altitude		
0 hrs	2hrs	18hrs	30hrs
0.0 (±0)	0.0 (±0)	2.375 * (±0.42)	1.625 * (±0.37)

* Asterisk denotes significant ($p<0.05$) difference in scores compared to baseline values at sea level before altitude exposure.

TABLE III: SUMMARY OF NEUROLOGICAL FINDINGS
(Number of subjects exhibiting abnormalities compared to sea level)

	Sea Level	Acute Altitude
Mental status:		
Short term memory	0	4
Long term memory	0	2
Serial Calculations	0	3
Cranial nerves:	0	0
Motor Examination:	0	0
Sensory Examination:	0	0
Reflexes:	0	0
Cerebellar/Equilibrium:	0	0

REFERENCES

1. Bruning JL, Kintz BL: Computational Handbook of Statistics. Glenview, IL: Scott, Foresman and Co. (1977), pp. 122-124.

2. Chiappa KH, Ropper AH: Evoked Potentials in Clinical Medicine. Part II. New Engl. J. Med. 306:1205-1211, 1982.

3. Colin E, Bourgain R, Manil J: Progressive alteration of somatosensory evoked potential waveforms with lowering of cerebral tisse PO_2 in the rabbit. Arch. Internatl. Physiologie Biochem. 86:677-679,1978.

4. Crow TJ, Kelman GR: Effect of mid acute hypoxia on human short term memory. Brit. J. Anaesth. 43:548-552, 1971.

5. Fraser WD, Eastman DE, Paul MA, Porlier JAG: Decrements in postural control during mild hypobaric hypoxia. Aviat. Space Environ. Med. 58:768-772, 1987.

6. Fulco CS, Cymerman A, Rock PB: A software package for administering and monitoring the Environmental Symptoms Questionnaire (ESQ-III). Aviat. Space Environ. Med. 56:872-877, 1985.

7. Goldie WD, Chiappa KH, Young RR, Brooks EB: Brainstem auditory and short-latency somatosensory evoked responses in brain death. Neurology 31:248-256, 1981.

8. Greene R: Mental performance in chronic anoxia. Brit. Med. J. 1:1028-1031, 1957.

9. Greene RG, Morgan DR: The effects of mild hypoxia on a logical reasoning task. Aviat. Space Environ. Med. 56:1004-1008, 1985.

10. Grundy BL, Heros HC, Tung AS, Doyle E: Intraoperative hypoxia detected by evoked potential monitoring. Anesth. & Analges. 60:437-439, 1981.

11. Hamilton AJ, Cymerman A, Black PM: High Altitude Cerebral Edema. Neurosurgery 19:841-849, 1986.

12. Kelman GR, Crow TJ, Bursill AE: Effect of mild hypoxia on mental performance as assessed by a test of selective attention. Aerospace Med. 40:301-303, 1969.

13. McFarland RA, Evans JN: Alterations in dark adaptation under reduced oxygen tensions. Am. J. Physiol. 127:37-50, 1939.

14. McFarland RA: Review of experimental findings in sensory and mental functions. In Hegnauer AH (Ed): Biomedicine of High Terrestrial Elevations. Washington, D.C., U.S. Army Medical Research and Development Command (1969), pp.250-265.

15. Rock PB, Johnson TS, Cymerman A, Burse RL, Falk LJ, Fulco CS: Effect of dexamethasone on symptoms of acute mountain sickness at Pikes Peak, Colorado (4,300 m). Aviat. Space Environ. Med. 58:668-672, 1987.

16. Sampson JB, Cymerman A, Burse RL, Maher JT, Rock PB: Procedures for the measurement of acute mountain sickness. Aviat. Space Environ. Med. 54:1064-1073, 1983.

17. Selvamurthy W, Saxena RK, Krishnamurthy N, Suri ML, Malhotra MS: Changes in EEG pattern during acclimatization to high altitude (3500 m) in man. Aviat. Space Environ. Med. 49:968-971, 1978.

18. Sutton LN, Cho B, Jaggi J, Joseph PM, Bruce DA: Effects of hydrocephalus and increased intracranial pressure on auditory and somatosensory evoked responses. Neurosurgery 18:756-761, 1986.

19. Townes BD, Hornbein T, Schoene RB, Sarnquist FH, Grant I: Human cerebral function at extreme altitude. In West JB, Lahiri S (Eds): High Altitude and Man. Bethesda, MD, American Physiological Society (1984), pp. 31-36.

20. Willer JC, Miserocchi G, Gautier H: Hypoxia and monosynaptic reflexes in humans. J. Appl. Physiol. 63:639-645, 1987.

21. Zeffiro T, Claman D: Trajectory properties of planar arm movements and the effect of visual guidance. (Abstr.) Society for Neuroscience. Fall Meeting 1985.

LEGENDS

Figure 1: A diagram depicting the dimensions and array of light-emitting diode targets employed in the upper extremity movement analyzer (UEMA).

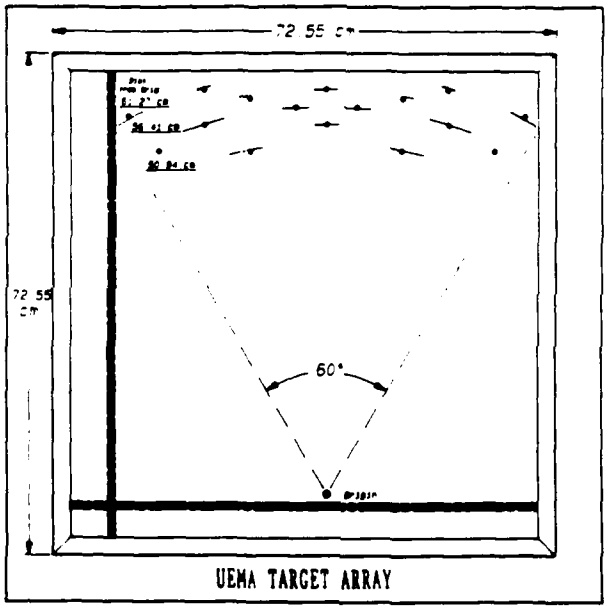
Figure 2: A systems diagram ilustrating the computer and digitizing tablet system emplyed in the upper extremity movement analyzer (UEMA). The computer is responsible for retrieving data assembled by the digitizer, analyzing the trials, and coordinating the random presentation of targets in the backlit array of light-emitting diodes.

Figure 3: A schematic representation of single trial employing UEMA. The origin and target are indicated in the square depicting the surface of the digitizing tablet. An ideal arm movement or path is shown and compared to a subject's actual path. The area of error (A_e) and length error (L_e) are indicated. See text for details.

Figure 4: A histogram showing mean peak velocity (V_p), average velocity (V_a), maximum acceleration (Acc), maximum deceleration (Dec), area error (A_e), and lenght error (L_e) of upper extremity arm movements from the group (n=8) of subjects exposed to simulated altitude of 4600m (15,000 ft). Sea level (SL) values were compared to values obtained at 30 hrs (n=8) of exposure. The asterisk indicates values which were significantly ($p \leq 0.05$) different from sea-level baseline data.

Figure 5: A line graph depicting changes in cerebral symptoms (mean AMS-C score) and mean clinical assessment scores during the 30 hr-long altitude exposure. See text for details.

Figure 6: A scattergram depicting individual AMS-C scores and percent decline of peak velocity (V_p) of upper extremity movements during altitude exposure. Included in this plot are four additional individual AMS-C scores and UEMA trials performed at 18 h of exposure (total n=12).



UEMA TARGET ARRAY

fig 1

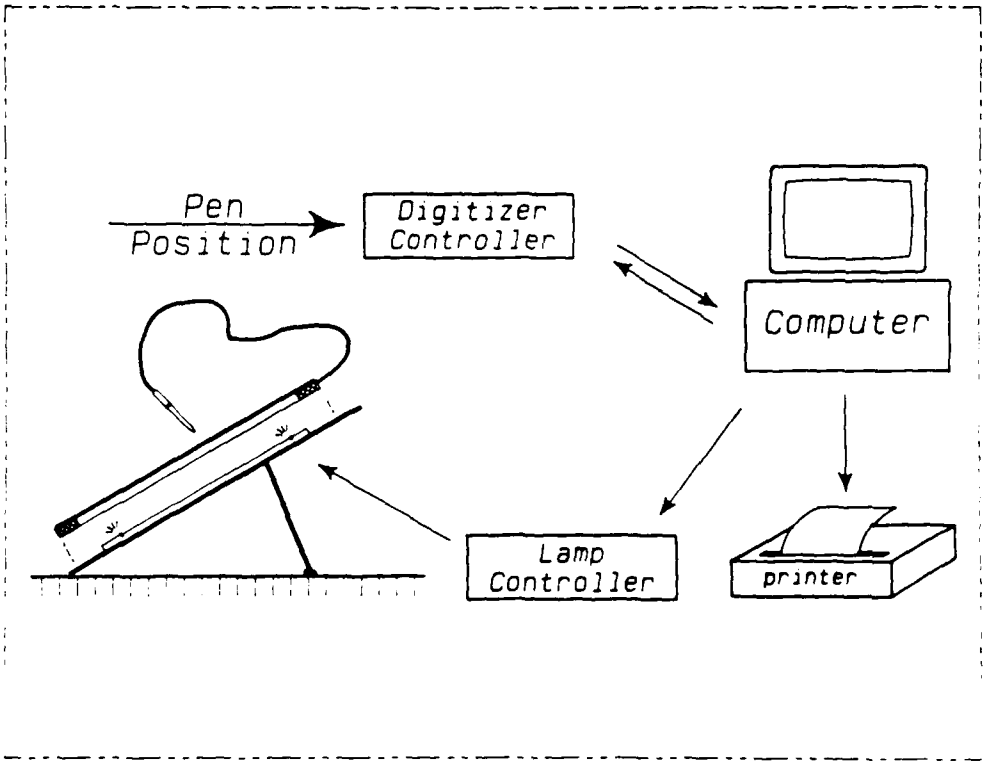

Pen
Position
Digitizer
Controller
Computer
Lamp
Controller
printer

fig. 2

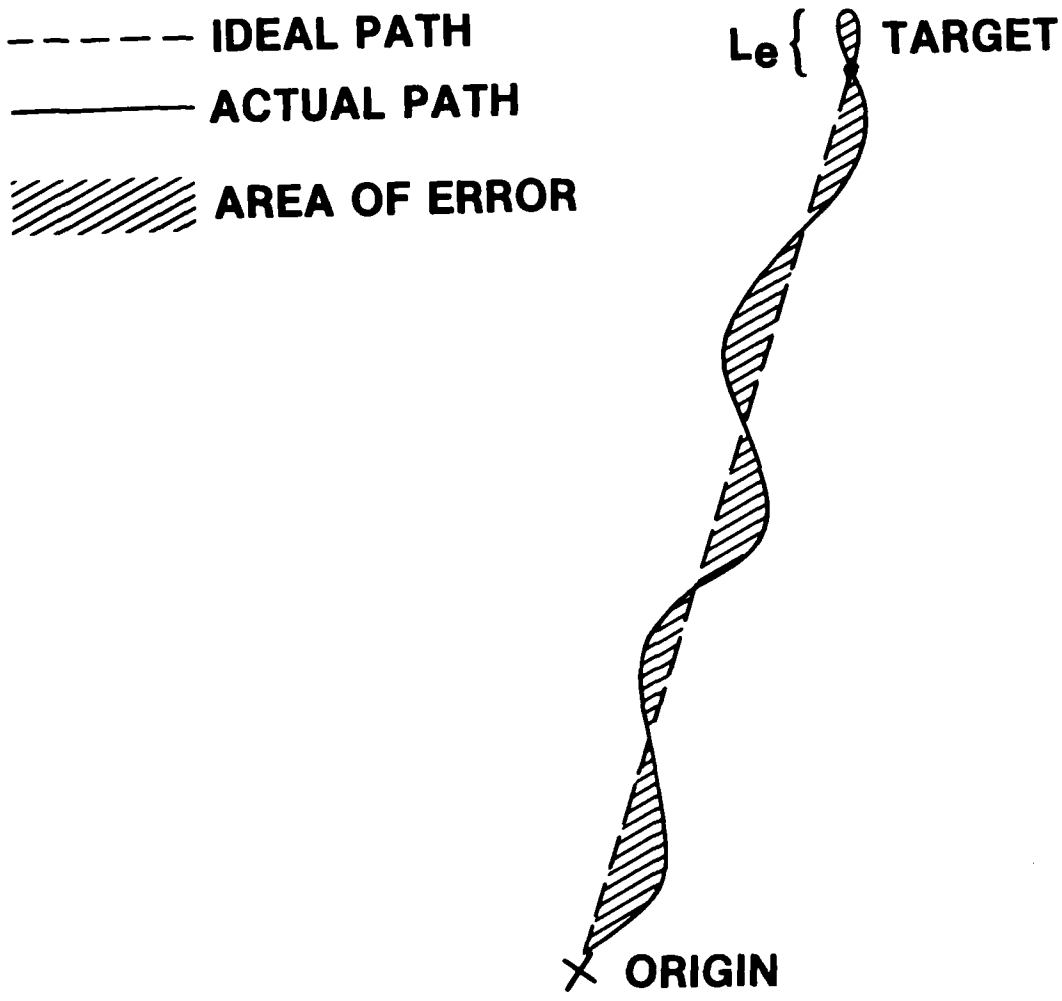


fig 2

ACUTE ALTITUDE EXPOSURE (4600 m)

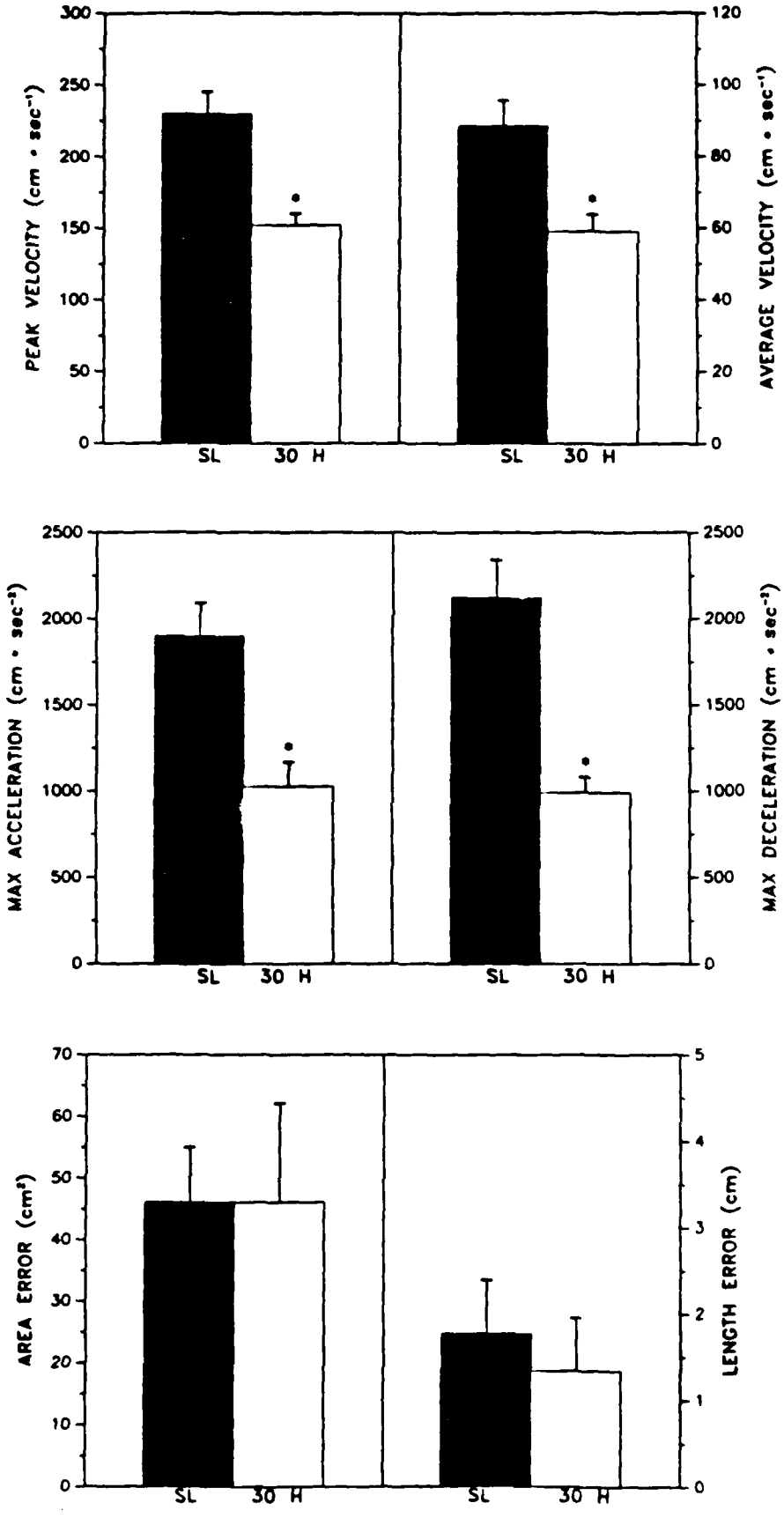


fig 4

ACUTE ALTITUDE EXPOSURE (4600 m)

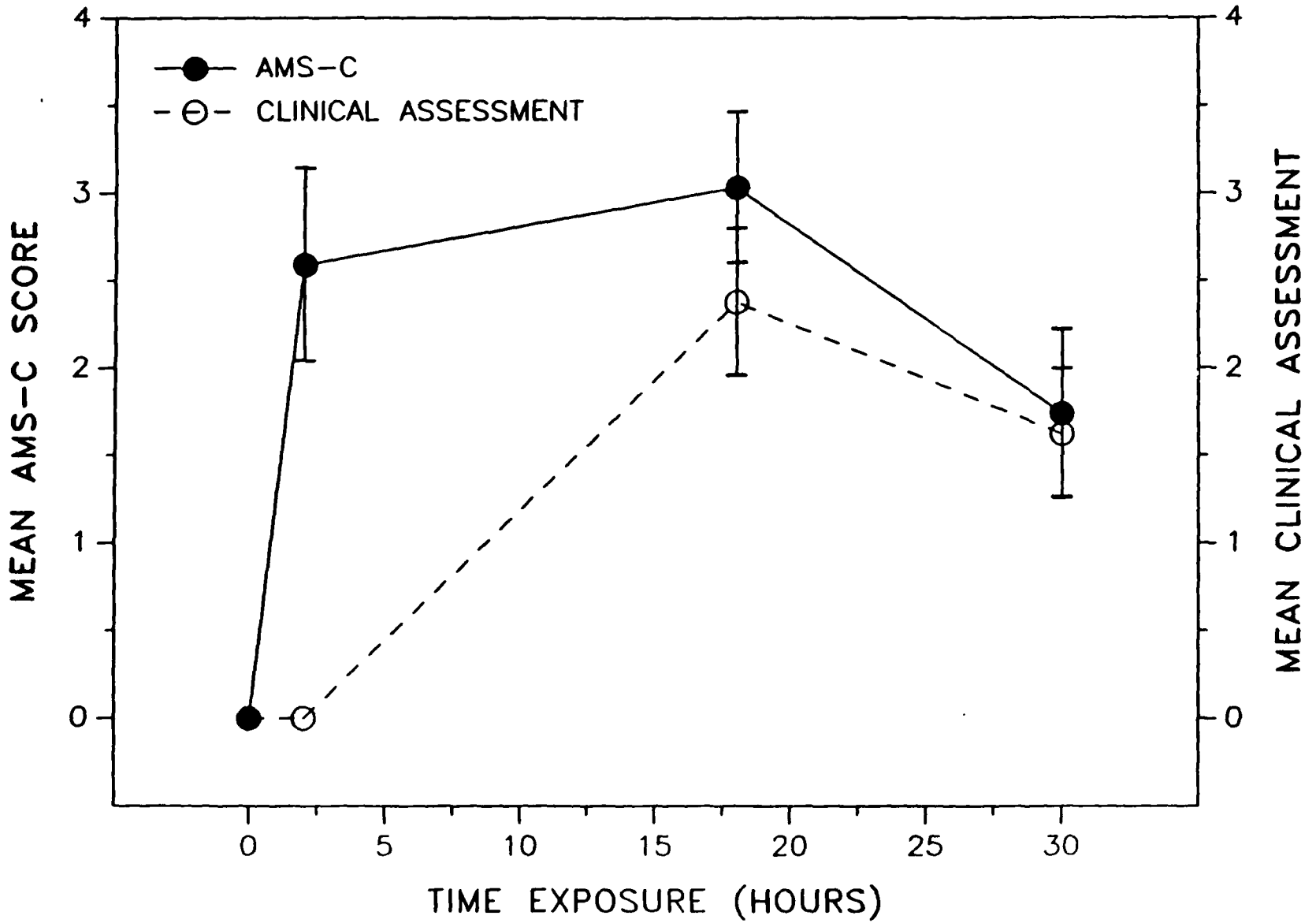
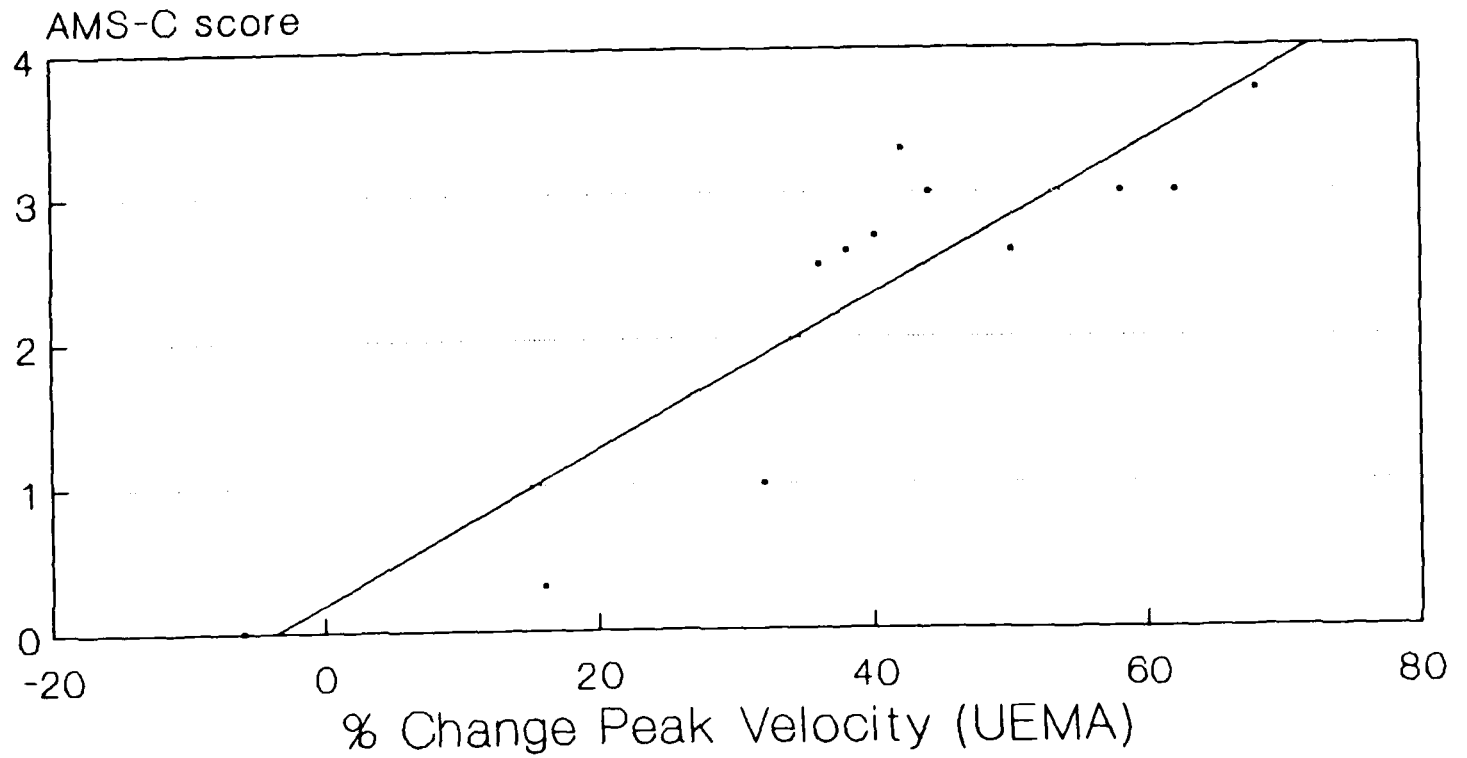


Fig. 5

AMS-C vs Peak Velocity
30 hour 4600 m Exposure



r<0.6667; df=10; p<0.02

fig 6

END

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